

## CLAIMS

1. A charge pump capable of having multiple stages, comprising:  
at least two pumping lines, each line including:  
an input terminal for accepting an input voltage,  
an output terminal for delivering an output voltage, the output voltage different than the input voltage,  
a pumping capacitor having a first terminal coupled between the input and output terminals and having a second terminal structured to accept a phase signal, and  
a switch coupled between the input terminal and the output terminal and structured to disrupt a connection between the terminals when activated by a switching signal;  
the charge pump further including:  
a switching network structured to couple the pumping lines either in a serial mode or a parallel mode depending on a state of the switching network.
2. The charge pump of claim 1 wherein there are at least four pumping lines, and the switching network comprises at least two switches.
3. The charge pump of claim 1 wherein some switches in the switching network and some of the switches in the pumping lines are structured to remain open during a charge pumping operation.
4. The charge pump of claim 1, further comprising:  
a control circuit including an optimal stages finder coupled to the switching network.
5. The charge pump of claim 4, further comprising a phase assigner coupled to the optimal stages finder, and comprising a plurality of multiplexing circuits.

6. The charge pump of claim 5 wherein some of the switches in the switching network and the switch in the pumping lines are structured to remain open during a charge pumping operation, and wherein the number in the plurality of multiplexing circuits is the same as the number of capacitors in the pumping lines plus the number of switches that do not remain open during the pumping operation.

7. The charge pump of claim 4 wherein the an optimal stages finder comprises a comparison circuit structured to compare a reference voltage to a power supply voltage and generate an output signal.

8. The charge pump of claim 7 wherein the comparison circuit comprises:  
a first resistor ladder coupled to the power supply voltage;  
a second resistor ladder coupled to the reference voltage; and  
a set of comparators.

9. The charge pump of claim 8 wherein inputs of the comparators are coupled to the resistor ladders, and wherein outputs of the comparators are coupled to a signal latching circuit.

10. The charge pump of claim 9 wherein the signal latching circuit comprises:  
a first input and a second input;  
a first and a second latch; and  
a logic circuit coupled between the first and second input and structured to provide a signal to the first and second latch based on a signal on the first and second input.

11. The charge pump of claim 10 wherein the logic circuit comprises an OR gate having a first input terminal coupled to the first input of the signal latching circuit, a second input terminal coupled to an inverted signal of the second input of the signal latching circuit, and having an output terminal coupled to the second latch.

12. A variable stage charge pump, comprising:  
a plurality of units, each unit including:  
an input terminal and an output terminal;  
a first switch coupled between the input terminal and a first terminal of a first capacitor, a second terminal of the first capacitor for receiving a pumping signal;  
a second switch coupled between the input terminal and a first terminal of a second capacitor, a second terminal of the second capacitor for receiving a second pumping signal;  
a third switch coupled between the first terminals of the first and the second capacitors;  
a fourth switch coupled between the first terminal of the first capacitor and the output terminal; and  
a fifth switch coupled between the first terminal of the second capacitor and the output terminal;  
a second plurality of phase selecting switches coupled to one of the capacitors in one of the units and structured to be coupled to one of the capacitors in another unit.

13. The charge pump of claim 12 wherein there are two units, and the phase selecting switch is coupled between the first terminal of the first capacitor of the first unit, and the first terminal of the first capacitor of the second unit.

14. The charge pump of claim 12 wherein the number of phase selecting switches in the second plurality is one less than the number of units in the plurality of units.

15. The charge pump of claim 14 wherein there are a first, second and third units and a first and second phase selecting switches, and wherein the first phase selecting switch is coupled between the first terminal of the first capacitor of the first unit and the first terminal of the first capacitor of the second unit, and the second phase selecting switch is coupled between

the first terminal of the second capacitor of the second unit and the first terminal of the second capacitor of the third unit.

16. The charge pump of claim 12, further comprising:  
a control circuit including an optimal stages finder coupled to the switching network.

17. The charge pump of claim 16, further comprising a phase assigner coupled to the optimal stages finder and comprising a plurality of multiplexing circuits.

18. A charge pump capable of having multiple stages, comprising:  
at least two pumping lines, each line including:  
an input terminal for accepting an input voltage,  
an output terminal for delivering an output voltage, the output voltage different than the input voltage,  
a pumping capacitor having a first terminal coupled between the input and output terminals and having a second terminal structured to accept a phase signal, and  
a switched diode coupled between the input terminal and the output terminal and structured to disrupt a connection between the terminals when activated by a switching signal;  
the charge pump further including:  
a switching network coupled between the pumping lines and structured to couple the pumping lines either in a serial mode or a parallel mode depending on a state of the switching network.

19. The charge pump of claim 18 wherein the switching network comprises:  
a first transistor coupled between the pumping lines;  
a second and a third transistor coupled between one of the pumping lines and a first terminal of an auxiliary capacitor; and

a fourth transistor coupled between the first terminal of the auxiliary capacitor and a reference voltage.

20. The charge pump of claim 19 wherein a control terminal of the second transistor is coupled to a signal that indicates the at least two lines of the charge pump should operate in a serial manner.

21. The charge pump of claim 19 wherein a control terminal of the fourth transistor is coupled to a signal that indicates the at least two lines of the charge pump should operate in a parallel manner.

22. The charge pump of claim 19 wherein a second terminal of the auxiliary transistor is structured to receive a phased signal.

23. The charge pump of claim 18, further comprising an output switched diode coupled to the output terminal.

24. The charge pump of claim 18 wherein the output switched diode comprises:

an input terminal and an output terminal;

a first transistor coupled between the input terminal and output terminal;

a second transistor coupled between the input terminal and a first node and a first capacitor;

a third transistor coupled between the input terminal and a first node of a second capacitor;

a fourth transistor coupled between a control gate of the first transistor and a reference voltage; and

a fifth transistor coupled between the first node of the second transistor and the reference voltage.

25. The charge pump of claim 24 wherein the control gate of the fourth transistor and the control gate of the fifth transistor are coupled and driven with a signal that disconnects the output switched diode from the output terminal of the charge pump.

26. A method of interconnecting a set of charge pumps each including phase switches and pumping capacitors, comprising:

accepting a voltage input signal at an input terminal;

applying a series of phase signals to the pumping capacitors and applying phase signals to the phase switches to produce an output voltage at an output terminal, the output voltage different than the input voltage; and

applying signals to a switching network coupled between the set of charge pumps, the signals for controlling whether the set of charge pumps should operate in a parallel or serial fashion.

27. The method of claim 26 wherein applying signals to a switching network comprises:

applying a signal to a switch coupled between two individual charge pumps.

28. The method of claim 26 wherein applying signals to a switching network comprises:

applying a first signal to a first switch coupled between a first and a second charge pump; and

applying a second signal to a second switch coupled between the second charge pump and a third charge pump.

29. The method of claim 26 wherein applying signals to a switching network comprises:

applying a first signal to a first transistor to cause the charge pumps to be coupled in a serial fashion, and applying a second signal to a second transistor in the switch network to cause the charge pumps to be coupled in a parallel fashion.

30. The method of claim 26 wherein applying signals to a switching network comprises:

connecting the output signal from one charge pump to the input signal of another charge pump.